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VERTICAL AND HORIZONTAL IN-RIVER FISH DISTRIBUTION, STIKINE RIVER, 1983

By:
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June 1984

ALASKA DEPARTMENT OF FISH AND GAME
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Don W. Collinsworth
Commissioner

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VERTICAL AND HORIZONTAL IN-RIVER FISH DISTRIBUTION,

STIKINE RIVER, 1983

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Alaska Department of Fish and Game
Division of Commercial Fisheries
Juneau, Alaska

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ABSTRACT

Hydroacoustic sampling of upstream migrant salmon in the Stikine River was conducted at two sites during three periods in the summer of 1983. Data were examined to determine fish horizontal, vertical, and temporal distributions, and optimal sample period duration. Equipment used for fish detection was capable of ensonifying a portion of the water column out to approximately 150 m from shore. Most fish (90-99%) migrated within 30 m of shore at the two sites sampled, and all detected fish were within 70 m of shore. Fish were distributed throughout the water column at both north and south bank sites. Distribution was similar between sites within and between time periods. Most fish were detected near the bottom between 9 and 13 July; a distributional shift to middle and surface waters was noted between 28 July and 1 August. Changes in distribution may reflect changes in species composition, river velocity, or other unknown factors. Temporal distributions of fish counts showed no consistency within or between periods. Coefficient of variation analysis indicated an optimal sampling period duration of 50 minutes.

KEY WORDS: Stikine River salmon, sonar research, salmon distribution.

INTRODUCTION

Hydroacoustic adult salmon counters developed by the Bendix Corporation[1] were used in the Stikine River in 1982 and 1983 to enumerate escapements of sockeye salmon *(Oncorhynchus nerka* Walbaum*)*. Counts were compared post-seasonally to estimates derived from a combination of upriver weir counts and scale pattern analysis for 1982 (Oliver 1983) and for 1983 (Walls 1984). In 1982, the total number of hydroacoustic counts allocated to sockeye salmon fell below the level of escapement estimated from weir counts and scale pattern data, and preliminary analysis of 1983 data indicates similar discrepancies between estimates derived by the two methods. Undercounting by the sonar units was severe enough to warrant an investigation of hydroacoustic operation.

Based upon the capabilities of the Bendix salmon counter, three potential sources of error were identified. First, the Bendix sidescanner is capable of ensonifying water out to a distance of 31 m. Fish migrating beyond this range would not be included in the escapement. Secondly, incomplete sampling occurred in both 1982 and 1983. During 1982, the beam[2] was aimed only along the bottom. In 1983, the beam was used to scan the bottom, middle, and upper parts of the water column. Thus, during 1982, fish not swimming on the bottom were not counted, and in 1983, fish not in the sampled strata were not counted. The final source of error is the method used to allocate counts to species. Sockeye and pink salmon *(O. gorbuscha)* runs overlap, and resident species such as Dolly Varden *(Salvelinus malma)* also add to the total counts. Catch data from bank-oriented fishwheels were used for species allocation in 1982, and data from both fishwheels and gillnets were used in 1983. The species allocation method is not addressed in this report but is being researched by other scientists.

In 1983, a study was undertaken to address the first two issues. The major objective of this study was to document the horizontal and vertical distributions of fish using more versatile sonar instrumentation. Secondary objectives included the examination of hourly fish counts and determination of the optimal length of the sampling period.

METHODS

Data Collection

Hydroacoustic sampling was conducted during three periods of summer, 1983; 14-16 June, 9-13 July, and 28 July - 1 August. The time frame was selected to sample the beginning, middle, and end of the sockeye salmon run. Two sites on the lower

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[1] Bendix Corporation Electrodynamics Division, 11600 Sherman Way, North Hollywood, California 91605.

[2] The Bendix salmon counter uses a combination 2°/4° beam (4° for the first half of the range scanned, 2° for the distant half).

Stikine River were used; one site was located on the north bank of the river, while the other site was located on the south bank (Figure 1). In addition to hydroacoustic sampling described below, Bendix side scan sonar units, providing escapement counts throughout the summer were located at these two sites. The entire river is contained within a single channel at this location, and the bottom profile is suitable for deployment of available hydroacoustic equipment. River bottom profile measurements were made on 14 June. At the north bank site, the river was nearly 6.5 m deep and 31 m offshore. Depth increased slightly with distance from that point to mid-river, then gradually increased to 7.7 m within 30 m of the south bank of the river (Appendix 1). The south bank site bottom slopes more gently away from shore and was only 3.6 m deep 31 m offshore. River depth increased with distance to a maximum of 9.7 m within 30 m of the north bank (Appendix 2). Water levels fluctuated through a range of approximately one meter (Appendix 3) over the three time periods sampled (USGS 1984).

Data acquisition equipment consisted of a Biosonics[1] 420 KHz Model 101 transceiver, 2° (narrow beam) and 6° (wide beam) transducers, a dual axis rotater for transducer aiming, a charter recorder, and an oscilloscope for monitoring the system. Transducers were attached to the Biosonics rotator system and mounted on a three-legged stand as depicted in Figure 2. This system allowed remote selection of X (upriver-downriver plane) and Y (surface to bottom plane) transducer angles.

The Biosonics 101 was chosen because of its extended range and versatility. High frequency (420kHz) was chosen in order to keep the cost and size of transducers at a minimum (for a given beam width, cost and transducer size decrease with an increase in frequency). High frequency also increases the target strength and allows use of short pulse lengths; both features are desirable for in-river fish enumeration.

An EPC[2] Model 1600 chart recorder recorded all returned echo information. It was chosen for its large paper size (223.5 mm) relative to other chart recorders. A threshold was placed before the chart recorder to allow display of only those fish equalling or surpassing a given target strength.

The transducer-rotater system was positioned near shore, and transducers were aimed slightly (15°) downstream to permit use of the change in range technique for distinguishing upstream from downstream movement of detected targets (Appendix 4). River depth profiles made prior to deployment of the equipment permitted positioning of acoustic "screens" in relatively discrete depth strata at both north and south bank sonar sites.

At each site, during each one-hour sampling interval, surface, midwater, and bottom depth strata were surveyed. Each strata was ensonified for a period of approximately 20 minutes within a sampling interval.

Chart recordings were examined, and site, date, time interval, beam width, transducer angle, and chart recorder setting data were recorded. Each detected target

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[1] Bionsonics Incorporated, 4520 Union Bay Place NE, Seattle, Washington 98105.

[2] EPC Laboratories, Inc., 5 Electronics Ave., Danvers, Maryland 01923.

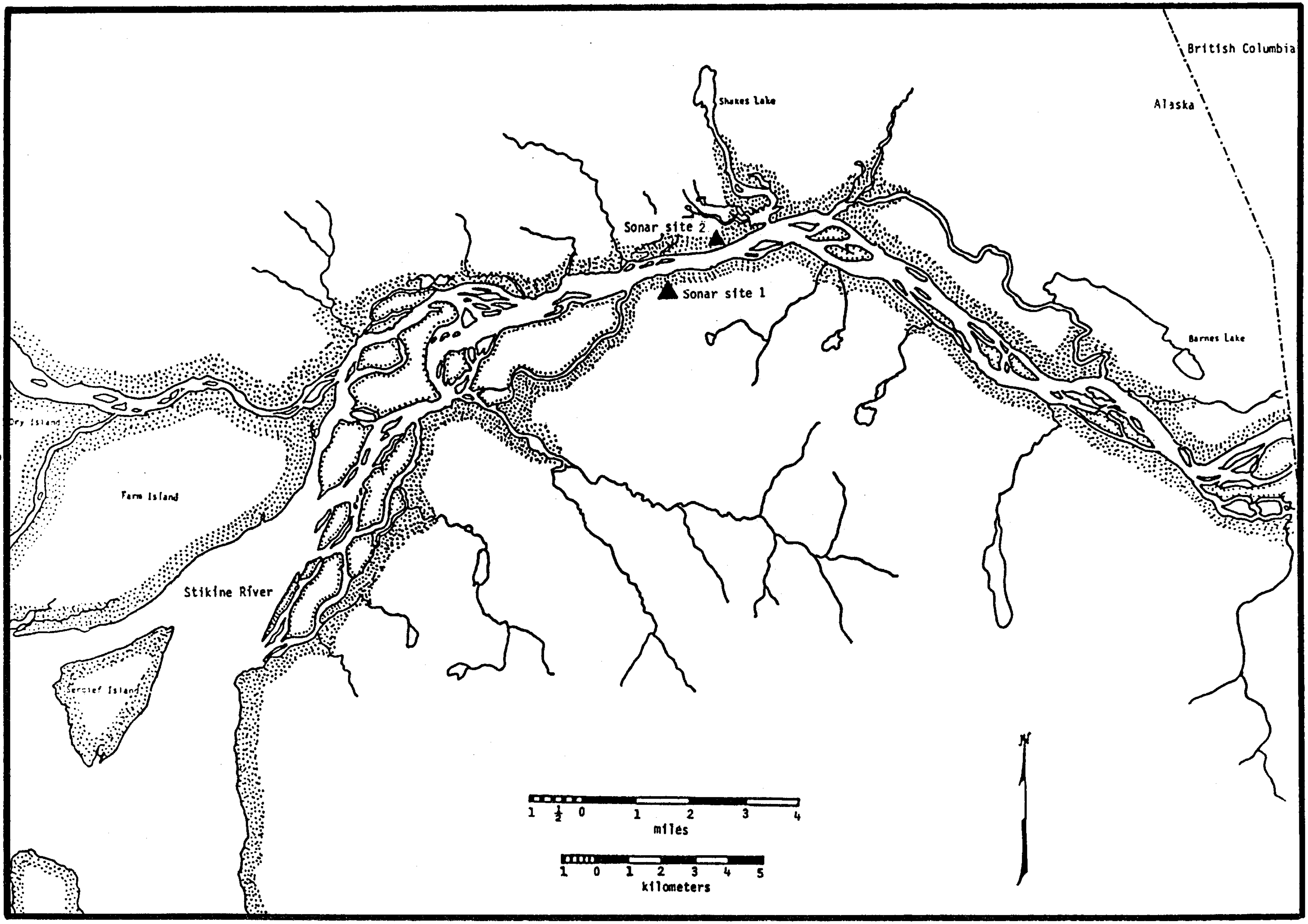

Figure 1. Map of the lower Stikine River showing the two sonar sampling sites.

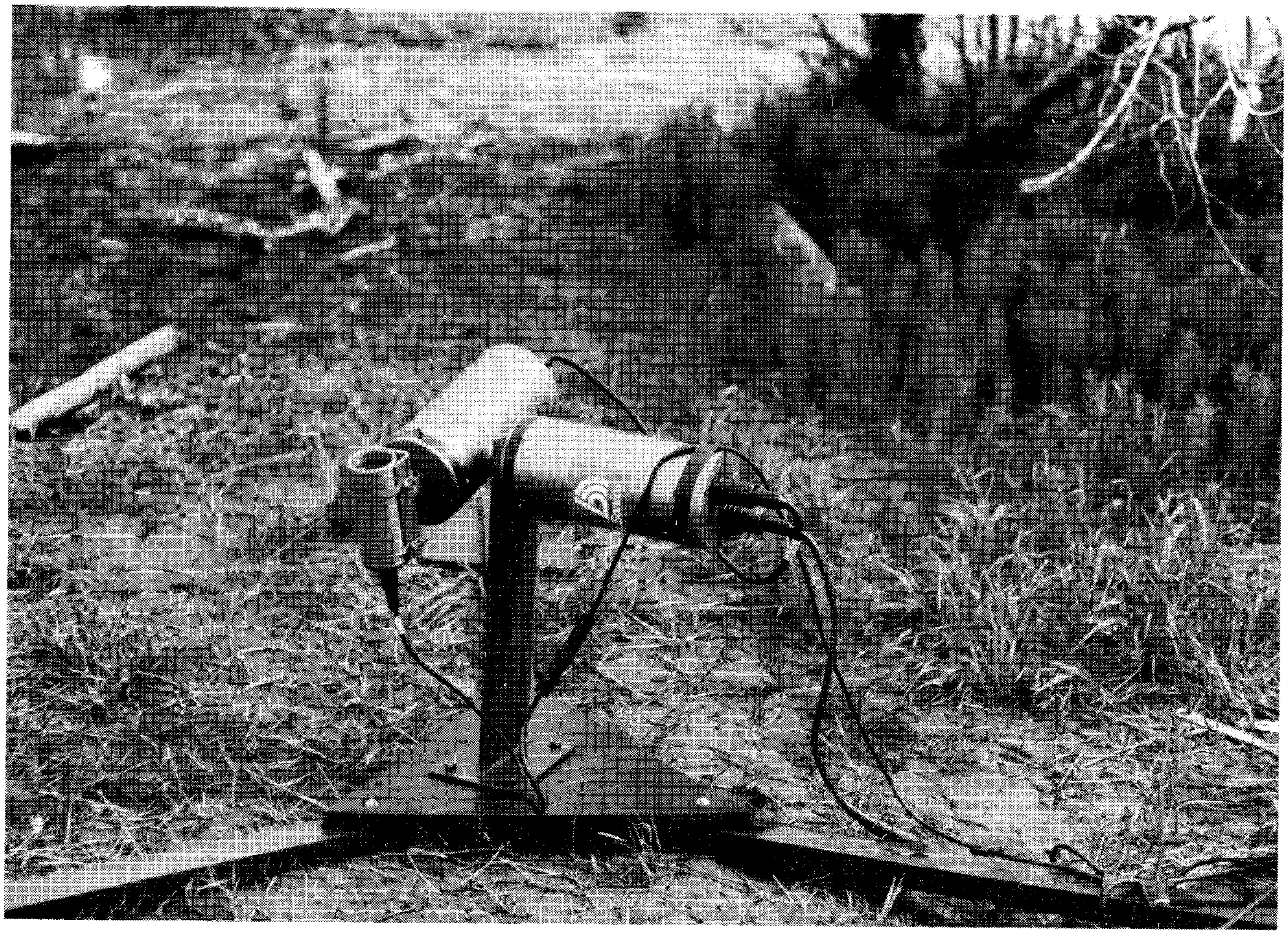

Figure 2. Transducer stand and rotater system used for hydroacoustic sampling in the Stikine River, 1983.

was classified as fish or debris based on criteria set forth in Appendix A. Measurements taken on targets classified as upstream migrants included time of day at beam entry, distance from the transducer at the point of beam entry and exit, target trace length, and trace angle relative to a line drawn perpendicular to shore. No analyses were performed on downstream directed fish targets.

Data Analysis

Data were examined to determine the horizontal distribution of upstream migrants. The distance offshore at which detected fish entered the sonar beam was determined by

$$D_{ij} = \frac{d_{ij}}{223.5} (T_i) (750) \cos (\phi + (0.5) (\alpha)).$$

where D_{ij} = Offshore distance (in meters) for the $_j$th fish in the $_i$th period.

d_{ij} = Distance (mm) from the zero line on the chart recorder to the first mark left by the fish.

T_i = Chart recorder time base setting, in seconds during period i.

ϕ = The angle (degrees) at which the transducer was aimed up or downriver relative to a line drawn perpendicular to the shoreline.

α = Beam width (degrees).

223.5 = Chart recorder paper width (mm).

750 = The round trip (transducer-target-transducer) velocity of sound in meters/second.

Fish were allocated to 10 m wide strata to estimate horizontal distribution. The number of detections in each stratum was normalized to compensate for increasing volumes of water sampled by each successive sector of the beam. Normalization was accomplished by multiplying the number of detections in each stratum by a constant developed for each beam sector based on the area within. The area of each sector was found by

$$A_n = \left[(0.5\ r_n{}^2) \frac{\alpha\ \pi}{180} \right] - \left[(0.5\ r_{n-1}{}^2) \frac{\alpha\ \pi}{180} \right]$$

where A_n = Area (m^2) within sector n.

r_n = Distance (m) from the transducer to the outer edge of sector n.

α = Beam width (degrees).

Normalizing constants for each sector were then found by

$$C_n = \frac{A_1}{A_n} 10$$

where C_n = Normalizing constant for sector n.

A_1 = Area (m^2) of sector 1.

A_n = Area (m^2) of sector n.

Normalizing constants range from 0.34 for the most distant (140-150 m) sector, to 10.0 for the ten meter wide sector nearest shore (Appendix 5).

Vertical distribution of upstream migrants was examined. Data were stratified by site, time period, beam width, and depth. Angles used for each of the depth strata varied slightly between and within dates due to such factors as changing river depth and differences in transducer attitude between surveys at the same site. The number of fish per minute migrating at each of three levels in the water column was calculated for each time period, site, and beam width by

$$N_{ij} = C_{ij}/P_{ij}$$

where N_{ij} = Average number of upstream migrants detected in stratum i during interval j.

C_{ij} = Number of upstream migrants detected in stratum i in interval j.

P_{ij} = Time (minutes) observed in stratum i during interval j.

The time of day of upstream migration was examined to determine whether there was a consistent daily pattern to fish migratory behavior in the Stikine River. Hourly counts were normalized by making the highest hourly count of each day equal to 1.0 and calculating normalized counts as

$$N_{ij} = \frac{C_{ij}}{H_{ij}}$$

where N_{ij} = Normalized count of upstream migrants during hour i on day j.

C_{ij} = Raw hourly count of upstream migrants during hour i on day j.

H_j = Highest hourly count of upstream migrants on day j.

Normalization of counts eliminates between-day variability, leaving within-day variability for analysis. Raw and normalized counts were allocated to one hour time periods. In those cases where no fish were detected, the midpoint of the sample interval was calculated and a zero was recorded in the appropriate hour stratum. When the midpoint fell exactly on the hour, it was rounded down.

The duration of the basic sampling unit, or optimal amount of time to spend sampling a specific stratum with a specific transducer, was determined using analysis of the coefficients of variation of fish counts recorded during sampling periods of different length. Sampling periods were divided into smaller periods, by five minute increments, and the mean, standard deviation, coefficient of variation, and 95% confidence intervals around the coefficient of variation were calculated.

In a search for a quick, easy method of estimating the variance of hydroacoustic escapement estimates in the Stikine River, the elapsed time between successive detections of upstream migrants was examined. If time between arrivals was Poisson distributed, the variance and mean would be equal and both would be easily determined. Thus, the sample variance of the frequency distribution of the time between successive arrivals may be compared to the mean of the frequency distribution in a one sample test of variance (Elliott 1971). Under the assumption that $S^2 = \bar{x}$, the following test statistic x^2 has a chi square distribution.

RESULTS AND DISCUSSION

Data were collected from the two Stikine River sonar sites during 13 days spread through three sampling periods (Table 1). Analysis of these data resulted in detection of 213 upstream directed fish. Only one fish was detected between 14 and 16 June; therefore, the analyses apply to fish passage which occurred between 9 and 13 July, and between 28 July and 1 August.

Horizontal Distribution

Horizontal distribution of Stikine River fish was determined at the north and south bank sites using both narrow- and wide- angle acoustic beams. The wide-angle beam is capable of ensonifying a portion of the water column to a range of approximately 75 m, while the narrow-angle beam ranged to 150 m. All fish detected at either of the two sites were within 70 m, and 90 to 99% were within 30 m of shore (Table 2). At the north bank site, over the two time periods when significant fish passage was detected, the majority of the fish detected were within 30 m of the transducer (Figures 3 and 4). Similarly, the vast majority of all fish detected at the south bank site over the same time frame were migrating within 30 m of the transducer face (Figures 5 and 6). A consistently higher proportion of fish were located within 20 m of shore at the south bank site than at the north bank site.

The proportion of all fish that were detected within 30 m of the transducer at both the north and south bank sites during the period 28 July to 1 August increased above what was found in the period 9-13 July. This change may be related to a change in species composition from primarily sockeye salmon to a mixture of sockeye, coho *(O. kisutch)*, and pink salmon. Pink salmon are known to travel very close to shore, large numbers were present in 1983, and no historical run timing data shows increasing pink salmon run strength after mid July (John E. Clark, personal communication).

Differences were also evident between beam widths within a site, with the narrow-angle beam tending not to detect as many fish within the first 10 m of shore as

Table 1. Sampling time and river strata examined by date, site, and beam width for the Stikine River sonar studies, 1983.

			Depth					
			Surface		Mid-Water		Bottom	
Date	Site	Beam[1] Width	Angle	Minutes	Angle	Minutes	Angle	Minutes
14 June	South Bank	2^{o}	40	19	45,47,49	81	55	20
		6^{o}	27	80	38	40	54,55	23
15 June	South Bank	2^{o}		0		0		0
		6^{o}	40	53	47	40	55	40
	North Bank	2^{o}		0		0		0
		6^{o}	29	62	34	65	39	50
16 June	North Bank	2^{o}		0		0		0
		6^{o}	29	120	34	100	39	76
9 July	South Bank	2^{o}		0		0		0
		6^{o}	28	32	31	74	34	40
10 July	South Bank	2^{o}	28	40	31	44	33,34	31
		6^{o}	28	151	31	186	34	144
11 July	South Bank	2^{o}	29	47	31	20	33	20
		6^{o}	28	20	31	67	33.34	62
	North Bank	2^{o}		0		0		0
		6^{o}	24	40	29,31	60	34,35	63
12 July	North Bank	2^{o}	30	20		0	36	22
		6^{o}	24,25,27	162	29,31	137	34,36	233
13 July	North Bank	2^{o}		0		0		0
		6^{o}	25	19	29	21	34	20
28 July	South Bank	2^{o}	40.41	49	42.43	41	46	38
		6^{o}	42	100		0	45	62
29 July	South Bank	2^{o}	40.41	94	42,43	140	45,46	159
		6^{o}	42	216		0	45	124
30 July	South Bank	2^{o}	40	50	42.43	50	45,46	50
		6^{o}	37-42	96		0	45	88
	North Bank	2^{o}	32	87		0	37	65
		6^{o}	35	82		0	42,43	89
31 July	North Bank	2^{o}	30.32	220	35.37.38	106	44,45	42
		6^{o}	35	180	39	53	42	104
1 August	North Bank	2^{o}		0	38	11	45	10
		6^{o}	35	13	39	11	42	10

[1] Narrow-angle beam = 2^{o}
Wide-angle beam = 6^{o}

Table 2. Proportions of the total number of fish detected within 10m horizontal strata by site, period, and beam width, in the Stikine River in 1983.

Inclusive Dates	Site	Beam Width[1]		Distance Offshore (m) 1-10	11-20	21-30	31-40	41-50	51-60	61-70
9 July to 13 July	South Bank	2°	%	55.60	27.59	8.24	0.00	5.05	0.00	3.53
			Cum. %	55.60	83.19	91.43	91.43	96.48	96.48	100.00
		6°	%	40.47	56.06	2.70	0.77	0.00	0.00	0.00
			Cum. %	40.47	96.53	99.23	100.00			
		$2\&6^{\circ}$	%	42.18	52.83	3.33	0.68	0.58	0.00	0.40
			Cum. %	42.18	95.01	98.34	99.02	99.60	99.60	100.00
	North Bank	2°	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Cum. %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		6°	%	19.46	44.77	25.95	7.66	0.00	2.16	0.00
			Cum. %	19.46	64.23	90.18	97.84	97.84	100.00	
		$2\&6^{\circ}$	%	19.46	44.77	25.95	7.66	0.00	2.16	0.00
			Cum. %	19.46	64.23	90.18	97.84	97.84	100.00	
28 July to 1 August	South Bank	2°	%	31.64	55.91	10.73	1.72	0.00	0.00	0.00
			Cum. %	31.64	87.55	98.28	100.00			
		6°	%	54.76	41.78	2.58	0.88	0.00	0.00	0.00
			Cum. %	54.76	96.54	99.12	100.00			
		$2\&6^{\circ}$	%	51.55	43.74	3.71	1.00	0.00	0.00	0.00
			Cum. %	51.55	95.29	99.00	100.00			
	North Bank	2°	%	35.01	41.84	10.00	13.15	0.00	0.00	0.00
			Cum. %	35.01	76.85	86.85	100.00			
		6°	%	47.48	38.92	13.60	0.00	0.00	0.00	0.00
			Cum. %	47.48	86.40	100.00				
		$2\&6^{\circ}$	%	44.72	39.57	12.80	2.91	0.00	0.00	0.00
			Cum. %	44.72	84.29	97.09	100.00			
9-13 July and 28 July to 1 August	South Bank	2°	%	36.77	49.84	10.19	1.36	1.08	0.00	0.76
			Cum. %	36.77	86.61	96.80	98.16	99.24	0.00	100.00
		6°	%	51.10	45.43	2.62	0.85	0.00	0.00	0.00
			Cum. %	51.10	96.53	99.15	100.00			
		$2\&6^{\circ}$	%	49.20	46.01	3.62	0.92	0.14	0.00	0.11
			Cum. %	49.20	95.21	98.83	99.75	99.89	99.89	100.00
	North Bank	2°	%	35.01	41.84	10.00	13.15	0.00	0.00	0.00
			Cum. %	35.01	76.85	86.85	100.00			
		6°	%	41.83	38.38	16.67	2.43	0.00	0.69	0.00
			Cum. %	41.83	80.21	96.88	99.31	99.31	100.00	
		$2\&6^{\circ}$	%	40.81	38.90	15.67	4.04	0.00	0.58	0.00
			Cum. %	40.81	79.71	95.38	99.42	99.42	100.00	

[1] Narrow-angle beam = 2°
Wide-angle beam = 6°

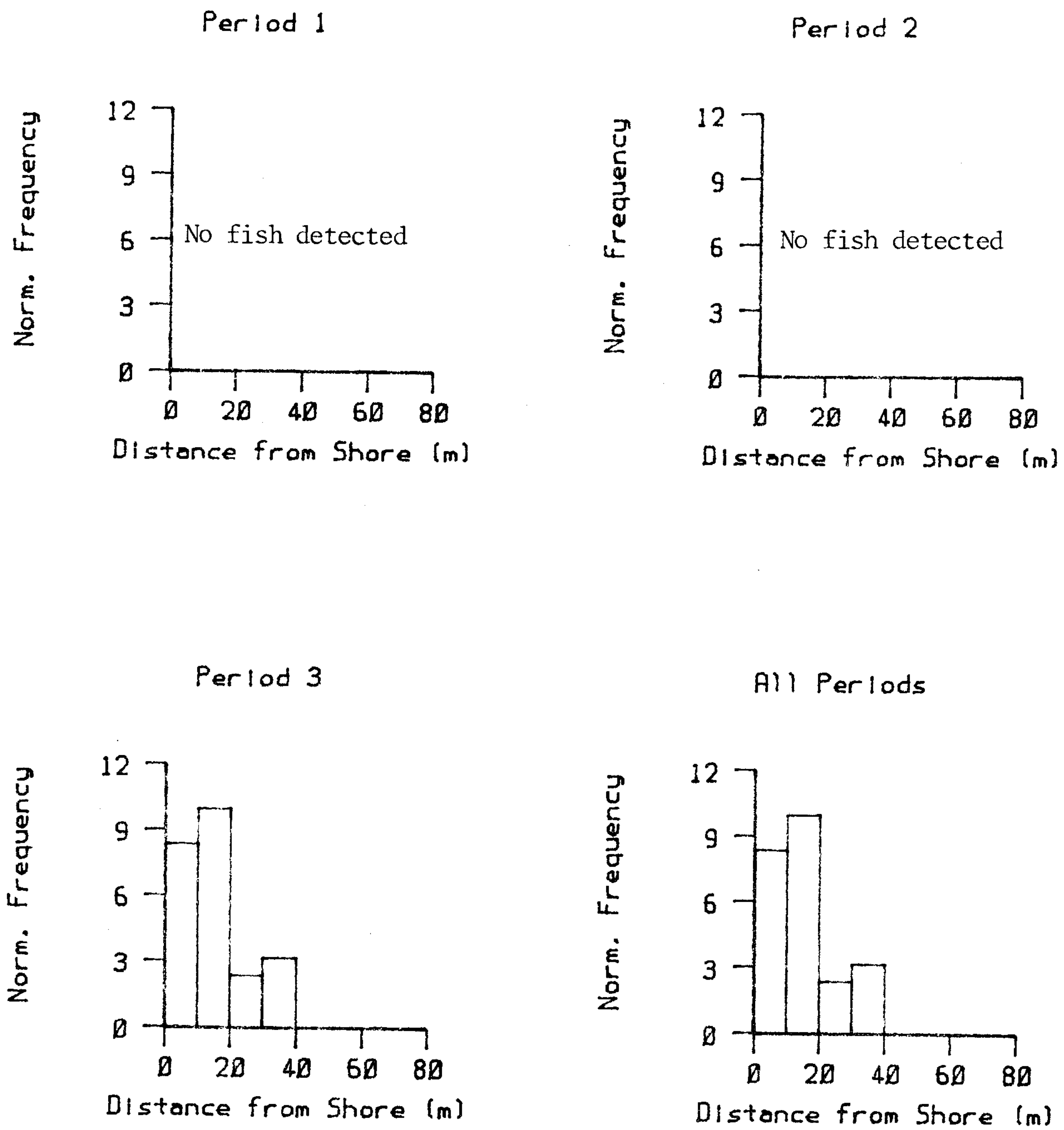

Figure 3. Horizontal distribution of Stikine River fish detected at the north bank sonar site with a narrow-angle (2°) beam, by period, 1983.

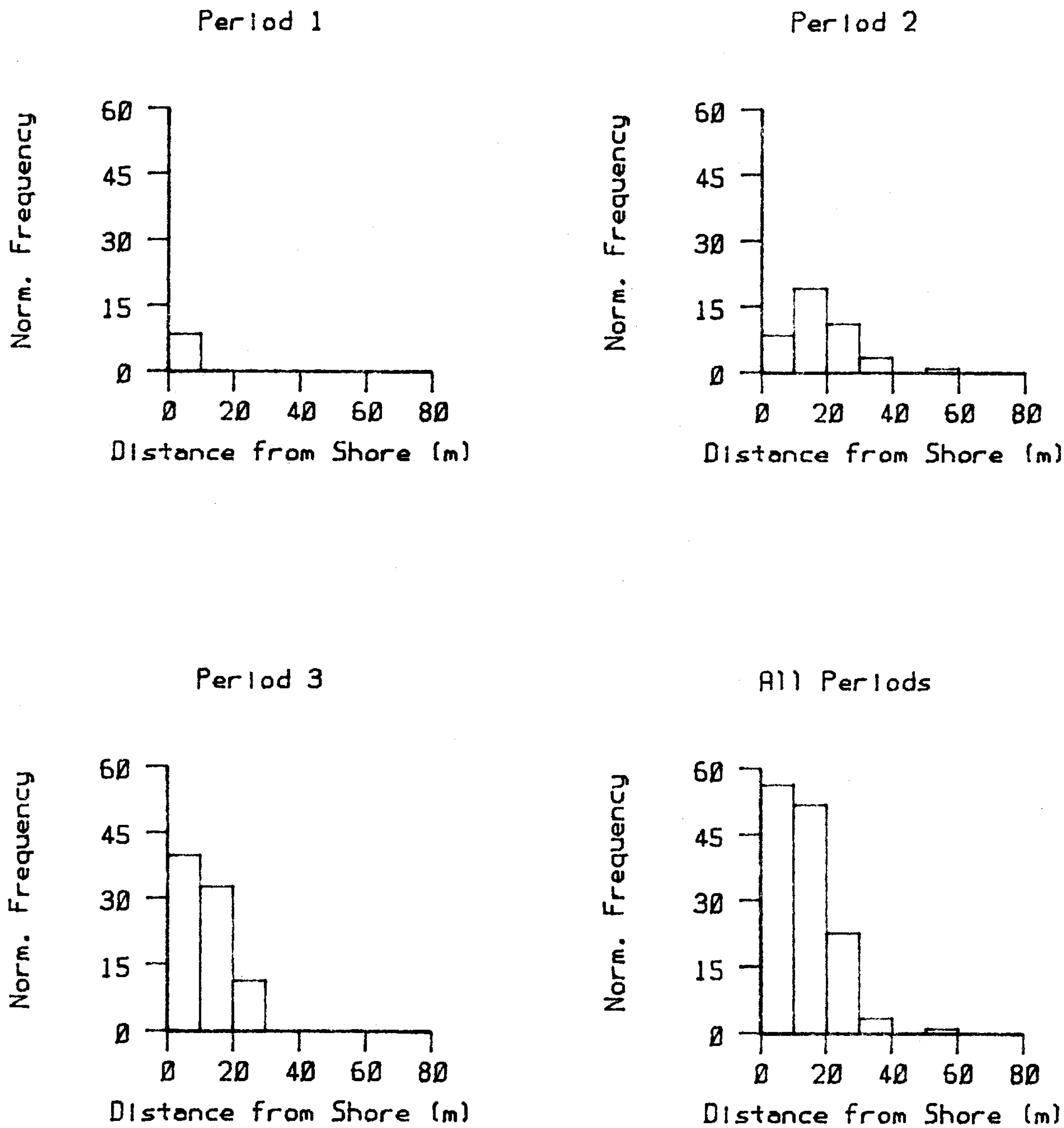

Figure 4. Horizontal distribution of Stikine River fish detected at the north bank sonar site with a wide-angle (6°) beam, by period, 1983.

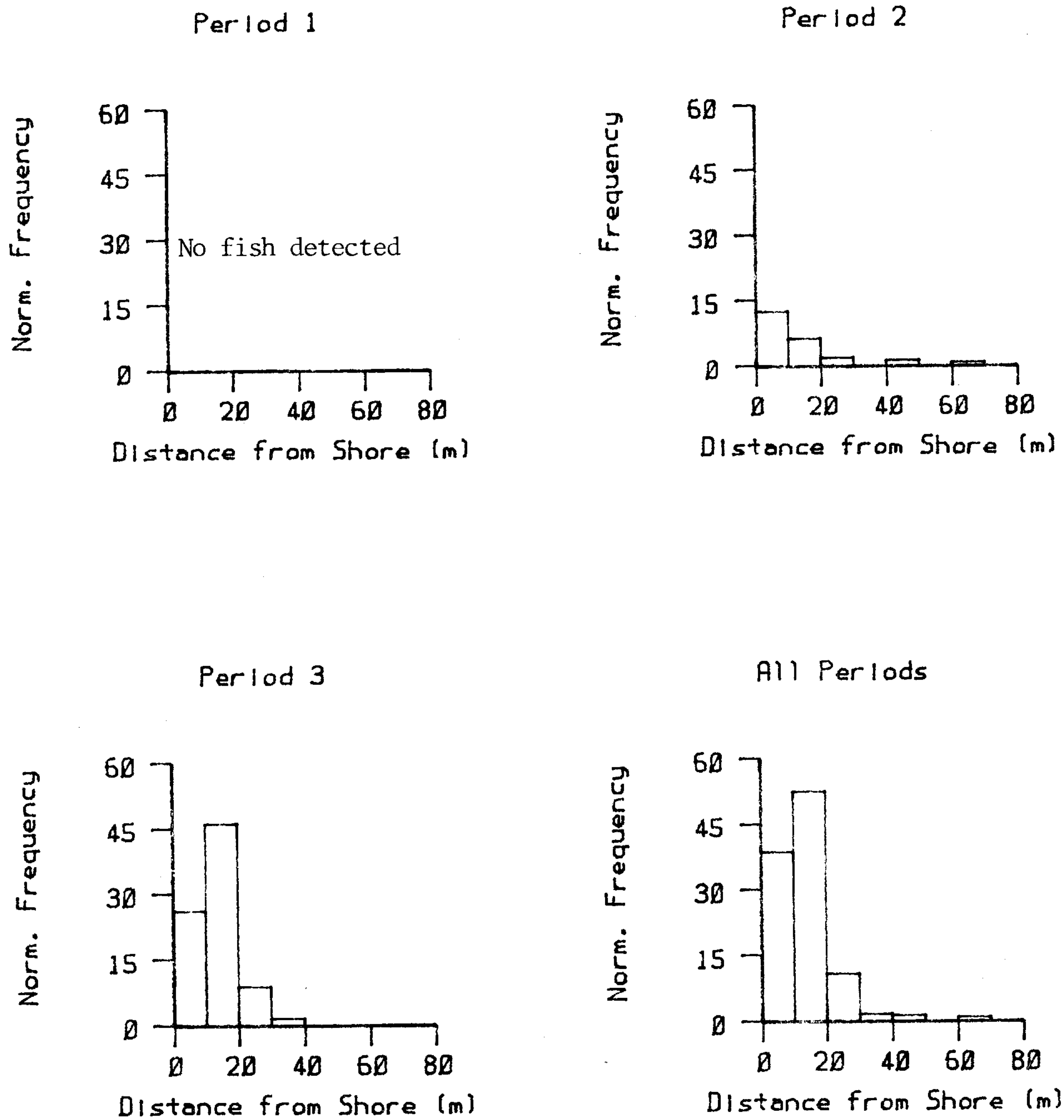

Figure 5. Horizontal distribution of Stikine River fish detected at the south bank sonar site with a narrow-angle (2°) beam, by period, 1983.

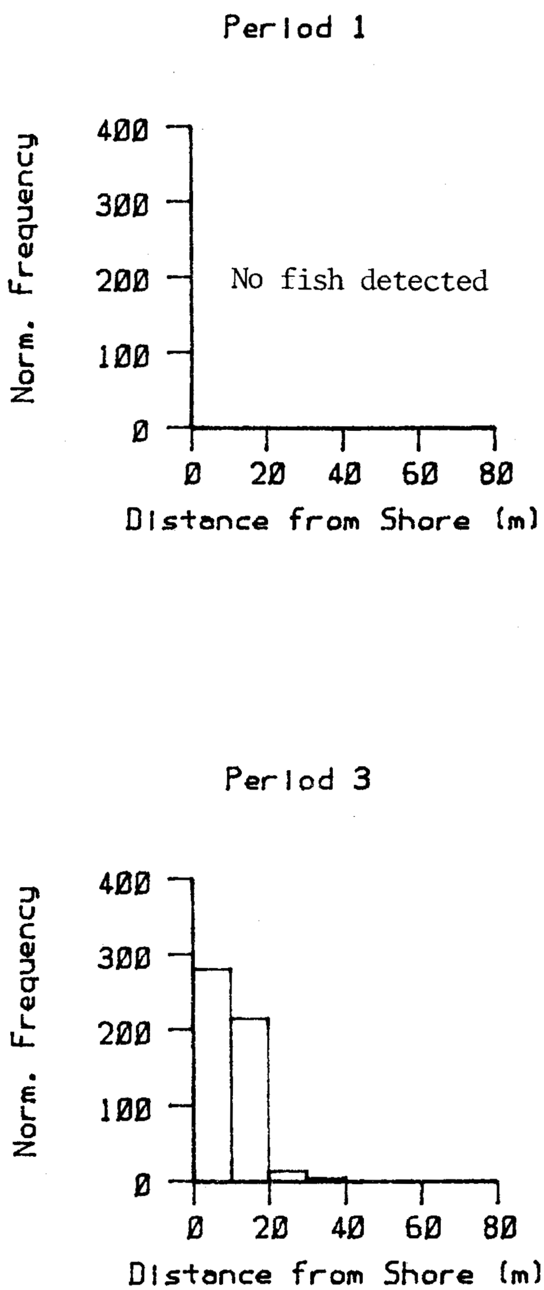

Figure 6. Horizontal distribution of Stikine River fish detected at the south bank sonar site with a wide-angle (6°) beam, by period, 1983.

did the wide-angle beam. This is probably due to the difference in width of the two beams near the transducer face. The narrow-angle beam is much narrower near its source than is the wide-angle beam. Fish passing close to the transducer are only in the beam for a short time, resulting in a short trace on the echogram. If the trace is too short to display a change in range from the transducer, the target will not be recognized as an upstream migrant and would instead be classified as debris. The wide-angle beam, therefore, gives a more accurate picture of horizontal distribution than does the narrow-angle beam, particularly in near-shore waters.

Vertical Distribution

The vertical distribution of upstream-migrant fish was assessed at the north and south bank sites using both narrow- and wide-angle hydroacoustic beams. Analysis of data from both sites revealed no consistent distributional trends within time periods between beam angles. Beam angles providing data most indicative of fish vertical distribution differ between sites, depending upon river bottom topography and sampling intensity. The narrow-angle beam provides more discrete samples of the water column than does the wide-angle beam, and is therefore most suitable for collection of vertical distribution data, particularly at sites with gently sloping bottom profiles. The wide-angle beam provides adequate information at sites deep enough to prevent overlap of vertical strata, and will generally provide larger sample sizes than the narrow-angle beam.

The wide-angle beam provided the best sample at the north bank site based on bottom topography and number of fish detected. Between 9 and 13 July, most (73.49%) fish at this site were migrating in the bottom stratum, and proportions of total fish detected decreased with increasing height in the water column (Table 3, Figure 7). A shift in distribution of fish from top and bottom strata to the middle stratum was noted during the period 28 July to 1 August. The proportion of the total number of fish detected with the 6° beam within the middle stratum changed from 17.75% to 50.19% between 13 July and 1 August, and numbers of fish migrating within both surface and bottom strata decreased (Table 3, Figure 7).

The narrow-angle beam provided the best vertical distribution data at the south bank sonar site. From 9 July to 13 July, the greatest proportion of fish (51.07%) were detected in the bottom strata, and decreasing proportions of the total were found with height in the water column (Table 3, Figure 8). Between 28 July and 1 August, however, the trend was reversed with 52.70% of all detected fish migrating near the surface and decreasing proportions migrating at depth.

Fish vertical distribution is consistent within each of the two time periods between the north and south banks. Most fish at both sites were detected in the bottom depth strata between 9 and 13 July, and a distributional shift to shallower strata was observed between 28 July and 1 August. The shift in vertical distribution over time is probably the result of changing species composition from primarily sockeye salmon to a mixture of sockeye, coho, and pink salmon.

Hourly Distribution

Hourly distribution of counts in important to determination of the frequency with which sampling must occur to permit estimation of total passage with a given level of precision. Raw hourly fish counts for all days sampled between 14 June and 1 August ranged from zero between 2000 and 2100 hours to 18 fish detected between

Table 3. Proportions of the total number of fish detected within vertical strata in the Stikine River by site, period, and beam width, 1983.

Inclusive Dates	Depth Strata	Site: South Bank, Beam width[1] 2^{o}	6^{o}	2 & 6^{o}	North Bank, Beam width 2^{o}	6^{o}	2 & 6^{o}
14 June to 16 June	Surface%	0.00	0.00	0.00	0.00	0.00	0.00
	Middle %	0.00	0.00	0.00	0.00	100.00	100.00
	Bottom %	0.00	0.00	0.00	0.00	0.00	0.00
9 July to 13 July	Surface%	20.74	20.51	20.08	0.00	8.76	8.50
	Middle %	28.19	52.79	49.53	0.00	17.75	18.79
	Bottom %	51.07	26.70	30.39	0.00	73.49	72.71
28 July to 1 August	Surface%	52.70	42.40	44.54	48.79	2.34	11.16
	Middle %	30.83	0.00	12.55	0.00	50.19	31.30
	Bottom %	16.47	57.60	42.92	51.21	47.47	57.54
Periods Combined	Surface%	48.65	34.43	39.06	51.52	4.70	11.92
	Middle %	29.02	23.67	22.87	0.00	28.54	24.66
	Bottom %	22.33	41.90	38.07	48.48	66.75	63.42

[1] Narrow-angle beam = 2^{o}
Wide-angle beam = 6^{o}

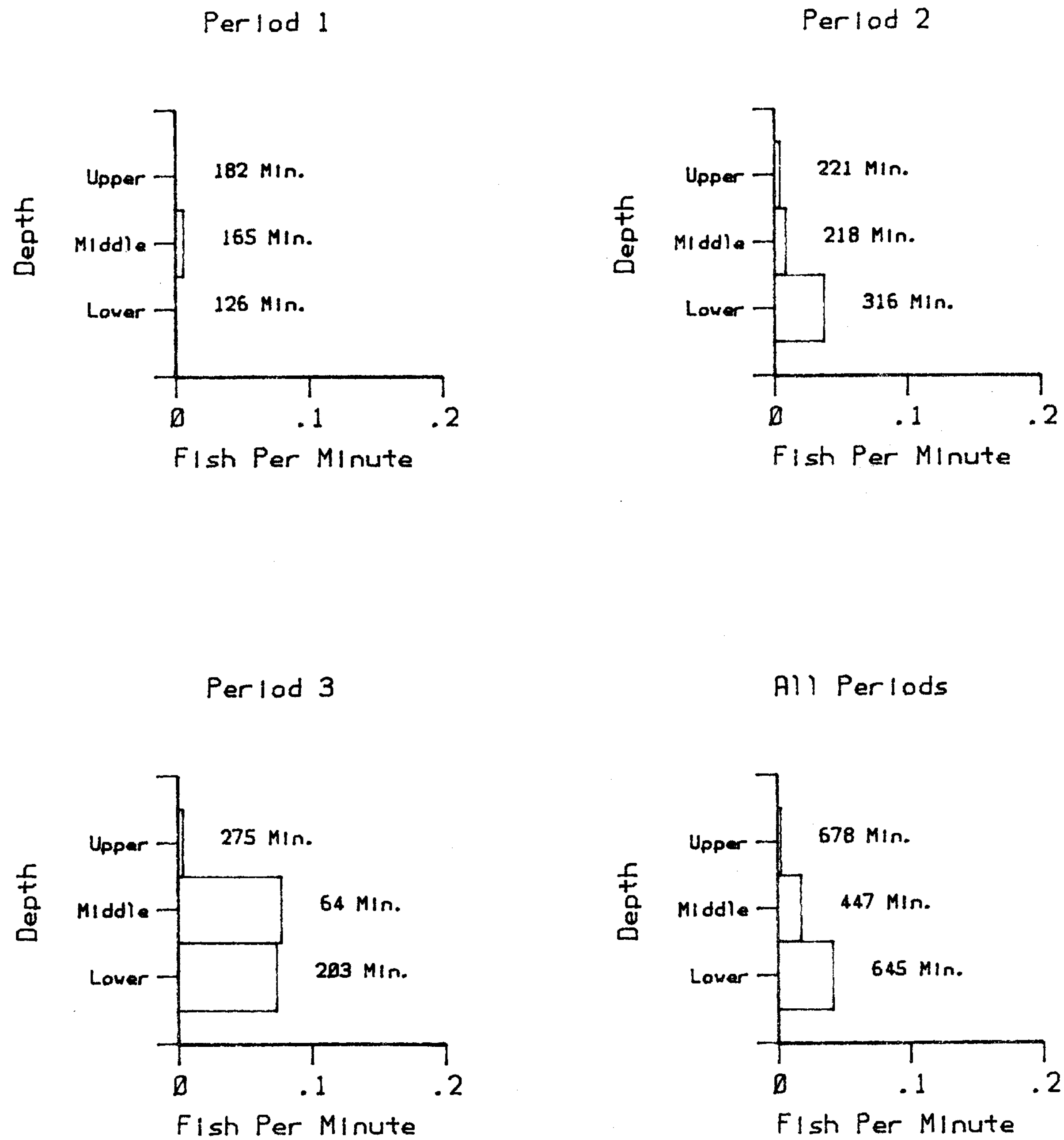

Figure 7. Vertical distribution of Stikine River fish detected at the north bank sonar site with a wide-angle (6°) beam, by period, 1983.

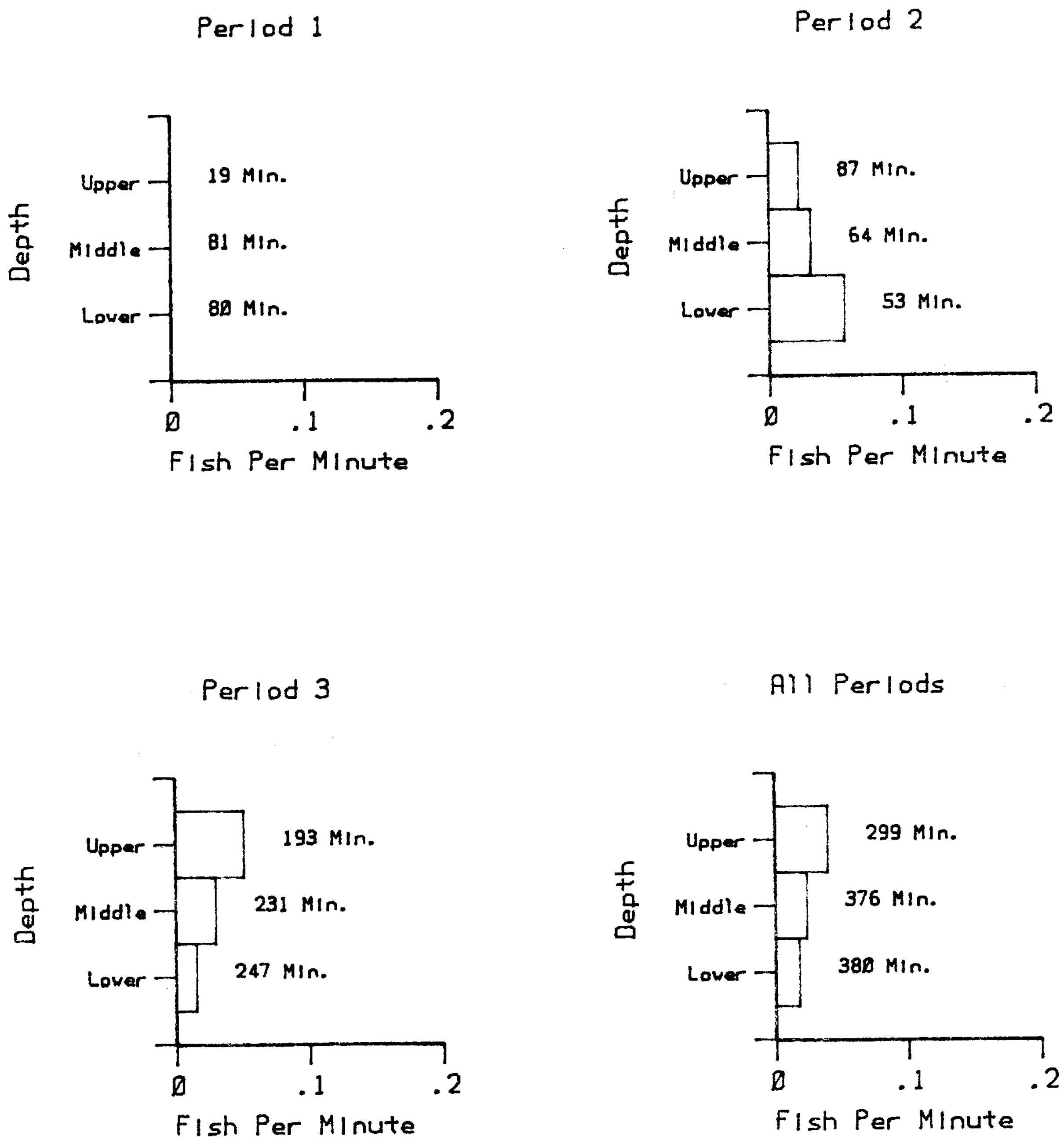

Figure 8. Vertical distribution of Stikine River fish detected at the south bank sonar site with a narrow-angle (2°) beam, by period, 1983.

0700 and 0800 hours (Table 4). Normalized hourly counts (Table 4, Figure 9) show no consistent trends in fish temporal distribution. Stikine River fish movement is apparently not related to time of day, but instead may be correlated with tides as suggested by Edgington and Lynch (1982).

Optimal Sampling Period Size

Analysis of the coefficients of variation of numbers of fish detected in sampling periods of various duration was undertaken in order to ascertain the optimal sampling period length. Observations of fish made with narrow- and wide-angle beams at the north and south bank sites were combined, and the data analyzed for each time period as well as for all time periods combined. The coefficient of variation for all time periods combined ranged from 133.936 for a 50-minute sampling period to 336.237 for a five-minute sampling period (Table 5, Figure 10). These data indicate that a 50-minute sampling period is required to minimize the coefficient of variation.

Time Between Successive Arrivals

The amount of time elapsed between successive arrivals of upstream migrant fish was calculated for each of the three time periods sampled. Agreement of arrival time distributions (Figure 11) to a Poisson distribution was rejected ($p < 0.05$). Arrival time is regularly distributed at both sites, therefore regular parametric methods of variance estimation must be used.

SUMMARY AND CONCLUSIONS

1. Fish migrating past sonar sites in the Stikine River display a horizontal distribution that is skewed to offshore sectors. From 90% to 99% of the fish detected using narrow (2°) and wide (6°) beams were located within 30 m of the transducer during the three time periods sampled, and all fish were within 70 m of shore.

2. Fish are distributed throughout the water column at both north and south bank sonar sites. Vertical distribution changes over time, probably coincident with major species composition changes.

3. Distribution of counts over 24 hour periods show no consistent trend.

4. The sampling time period during which observations are made should be set at 50 minutes based upon analysis of the coefficient of variation of counts for various size sampling intervals.

Table 4. Hourly counts of upstream migrant fish in the Stikine River, by date, for all sampling periods, 1983.

Date	Type of Count	0000 to 0100	0100 to 0200	0200 to 0300	0300 to 0400	0400 to 0500	0500 to 0600	0600 to 0700	0700 to 0800	0800 to 0900	0900 to 1000	1000 to 1100	1100 to 1200	1200 to 1300	1300 to 1400	1400 to 1500	1500 to 1600	1600 to 1700	1700 to 1800	1800 to 1900	1900 to 2000	2000 to 2100	2100 to 2200	2200 to 2300	2300 to 2400
6/14	Raw	-	-	-	-	-	-	-	0	-	-	-	0	0	0	-	0	0	-	0	-	-	-	0	0
	Norm.	-	-	-	-	-	-	-	0	-	-	-	0	0	0	-	0	0	-	0	-	-	-	0	0
6/15	Raw	-	0	0	-	-	-	-	0	0	-	-	-	-	-	-	-	0	-	0	0	-	-	1	-
	Norm.	-	0	0	-	-	-	-	0	0	-	-	-	-	-	-	-	0	-	0	0	-	-	1.0	-
6/16	Raw	-	0	-	-	0	0	-	0	0	-	0	-	-	0	-	-	-	-	-	-	-	-	-	-
	Norm.	-	0	-	-	0	0	-	0	0	-	0	-	-	0	-	-	-	-	-	-	-	-	-	-
7/09	Raw	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	0	-	-	-	0	-	-
	Norm.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0	0	-	-	-	0	-	-
7/10	Raw	-	-	-	3	1	-	-	5	-	0	2	-	1	2	-	0	2	0	0	-	-	2	1	-
	Norm.	-	-	-	0.6	0.2	-	-	1.0	-	0	0.4	-	0.2	0.4	-	0	0.4	0	0	-	-	0.4	0.2	-
7/11	Raw	2	-	-	-	-	-	7	1	3	8	-	2	0	-	-	-	-	-	-	-	0	0	1	1
	Norm.	0.3	-	-	-	-	-	0.9	0.1	0.4	1.0	-	0.3	0	-	-	-	-	-	-	-	0	0	0.1	0.1
7/12	Raw	0	0	1	-	1	2	-	2	-	-	0	0	-	0	2	-	2	0	0	0	0	-	-	2
	Norm.	0	0	0.5	-	0.5	1.0	-	1.0	-	-	0	0	-	0	1.0	-	1.0	0	0	0	0	-	-	1.0
7/13	Raw	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Norm.	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7/28	Raw	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	10	0	0	4	2	-	7	0	-
	Norm.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6	1.0	0	0	0.4	0.2	-	0.7	0	-
7/29	Raw	3	1	-	2	3	3	2	3	7	0	-	1	8	13	6	0	-	-	3	3	-	4	0	-
	Norm.	0.2	0.1	-	0.2	0.2	0.2	0.2	0.2	0.5	0	-	0.1	0.6	1.0	0.5	0	-	-	0.2	0.2	-	0.3	0	-
7/30	Raw	3	5	7	6	1	5	2	5	-	-	-	-	0	0	-	5	0	-	0	0	-	0	0	-
	Norm.	0.4	0.7	1.0	0.9	0.1	0.7	0.3	0.7	-	-	-	-	0	0	-	0.7	0	-	0	0	-	0	0	-
7/31	Raw	2	1	0	3	0	-	0	2	-	2	0	-	0	0	1	0	5	0	-	-	-	1	4	-
	Norm.	0.4	0.2	0	0.6	0	-	0	0.4	-	0.4	0	-	0	0	0.2	0	1.0	0	-	-	-	0.2	0.0	-
8/01	Raw	2	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Norm.	1.0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	Raw	13	7	8	14	6	10	11	18	10	10	2	3	9	15	15	15	11	0	7	5	0	14	7	3
	Norm.	0.7	0.4	0.4	0.8	0.3	0.6	0.6	1.0	0.6	0.6	0.1	0.2	0.5	0.8	0.8	0.8	0.6	0	0.4	0.3	0	0.8	0.4	0.2

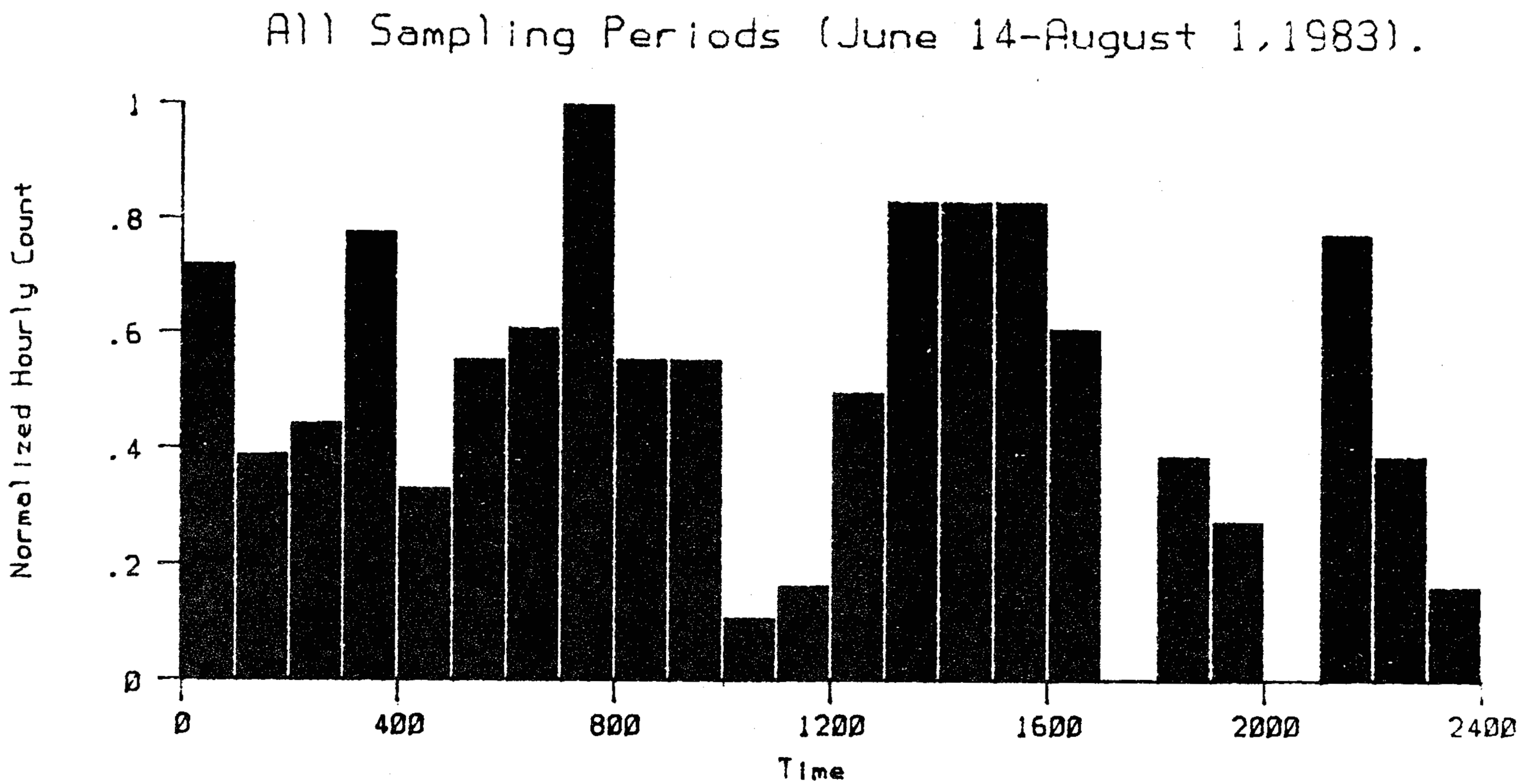

Figure 9. Hourly distribution of upriver migrant fish in the Stikine River during all sampling periods, 1983.

Table 5. Coefficient of variation and associated statistics for sampling time intervals used to detect upriver passage of fish with both 2^{o} and 6^{o} sonar transducers in the Stikine River in 1983.

Period and Dates	Time Interval (Minutes)	Number of Intervals Observed	Number of Fish Detected	Mean Number of Fish/Interval	Standard Deviation	Coefficient of Variation	Standard Deviation CV	Lower 95% Confidence Limit	Upper 95% Confidence Limit
	5	161	1	0.006	0.079	1268.860	1270.830	-1272.800	3810.510
1	10	79	1	0.013	0.112	888.820	891.628	- 894.436	2672.080
	15	49	1	0.020	0.143	700.000	703.563	- 707.125	2107.130
	20	37	1	0.027	0.164	608.276	612.372	- 616.469	1833.020
	25	25	1	0.040	0.200	500.000	504.975	- 509.951	1509.950
14 June	30	22	1	0.045	0.213	469.042	474.342	- 479.642	1417.720
to	35	15	1	0.067	0.258	387.298	393.700	- 400.102	1174.700
16 June	40	13	1	0.077	0.277	360.555	367.423	- 374.292	1095.400
	45	11	1	0.091	0.302	331.662	339.117	- 346.571	1009.900
	50	11	1	0.091	0.302	331.662	339.117	- 346.571	1009.900
	55	11	1	0.091	0.302	331.662	339.117	- 346.571	1009.900
	60	9	1	0.000	0.000	0.000	0.000	0.000	0.000
	5	309	54	0.175	0.626	358.011	74.323	209.365	506.657
2	10	151	54	0.358	1.060	296.538	73.567	149.405	443.672
	15	94	54	0.574	1.448	252.050	68.055	115.940	388.160
	20	72	54	0.750	1.860	247.934	75.333	97.268	398.600
	25	48	52	1.083	2.191	202.266	62.555	77.156	327.376
09 July	30	42	52	1.238	2.304	186.081	57.157	71.767	300.395
to	35	29	48	1.655	2.636	159.256	51.531	56.195	262.317
13 July	40	26	48	1.846	2.723	147.502	47.318	52.866	242.139
	45	21	48	2.286	2.866	125.390	39.389	46.612	204.168
	50	20	48	2.400	2.891	120.458	37.623	45.212	195.704
	55	19	48	2.526	2.913	115.305	35.780	43.745	186.865
	60	17	44	2.588	3.083	119.131	40.028	39.075	199.188
	5	466	150	0.322	0.884	274.758	36.110	202.537	346.979
3	10	227	150	0.661	1.572	237.980	39.214	159.552	316.407
	15	142	144	1.014	2.070	204.091	36.993	130.105	278.078
	20	107	145	1.355	2.839	209.517	44.789	119.939	299.095
	25	78	144	1.846	3.422	185.407	41.658	102.092	268.723
28 July	30	64	144	2.250	3.716	165.161	37.091	90.978	239.343
to	35	51	143	2.804	3.980	141.946	31.521	78.905	204.987
1 August	40	48	139	2.895	4.096	141.440	32.283	76.875	206.005
	45	32	112	3.500	4.008	114.516	27.246	60.025	169.007
	50	27	108	4.000	4.123	103.078	24.797	53.484	152.670
	55	24	103	4.292	4.408	102.717	26.147	50.424	155.010
	60	23	103	4.478	4.689	104.709	27.586	49.537	159.882
	5	959	206	0.215	0.722	336.237	37.306	261.625	410.848
All Periods	10	468	206	0.440	1.273	289.309	39.829	209.651	368.966
	15	292	200	0.685	1.700	248.204	37.486	173.231	323.176
	20	221	201	0.910	2.292	252.057	44.387	163.284	340.831
	25	155	198	1.277	2.790	218.438	40.284	137.871	299.006
14 June	30	131	198	1.511	3.011	199.224	36.797	125.630	272.818
to	35	97	193	1.990	3.362	168.963	31.423	106.118	231.808
1 August	40	89	189	2.124	3.480	163.867	31.000	101.866	225.868
	45	66	162	2.454	3.438	140.073	27.054	85.965	194.182
	50	60	158	2.633	3.527	133.936	26.188	81.559	186.312
	55	56	153	2.732	3.685	134.887	27.452	79.984	189.791
	60	50	148	2.960	3.974	134.264	28.813	76.638	191.890

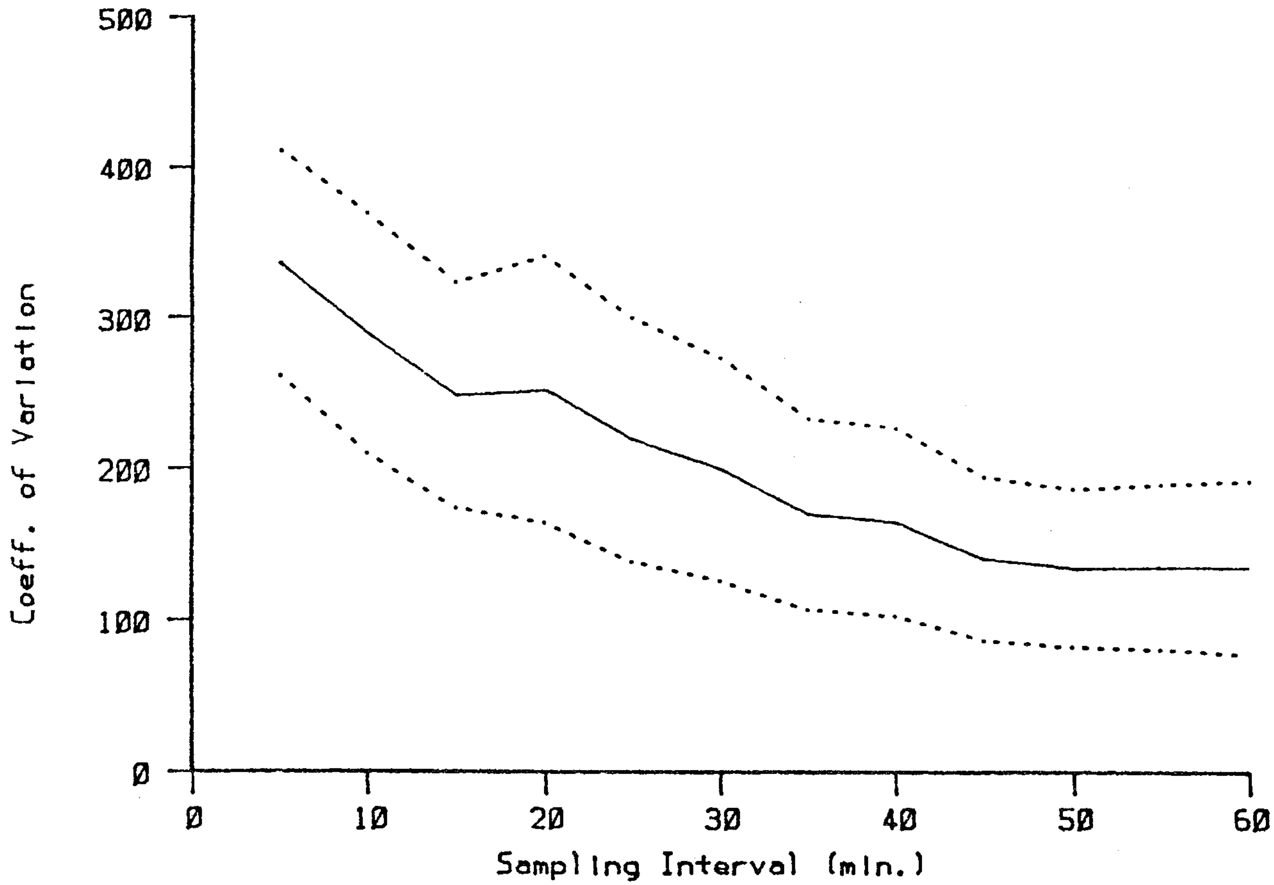

Figure 10. Relationship (with 95% confidence limits) between the coefficient of variation of fish counts and sampling interval duration for Stikine River fish detected during all sampling periods with narrow-angle (2°) and wide-angle (6°) sonar beams, 1983.

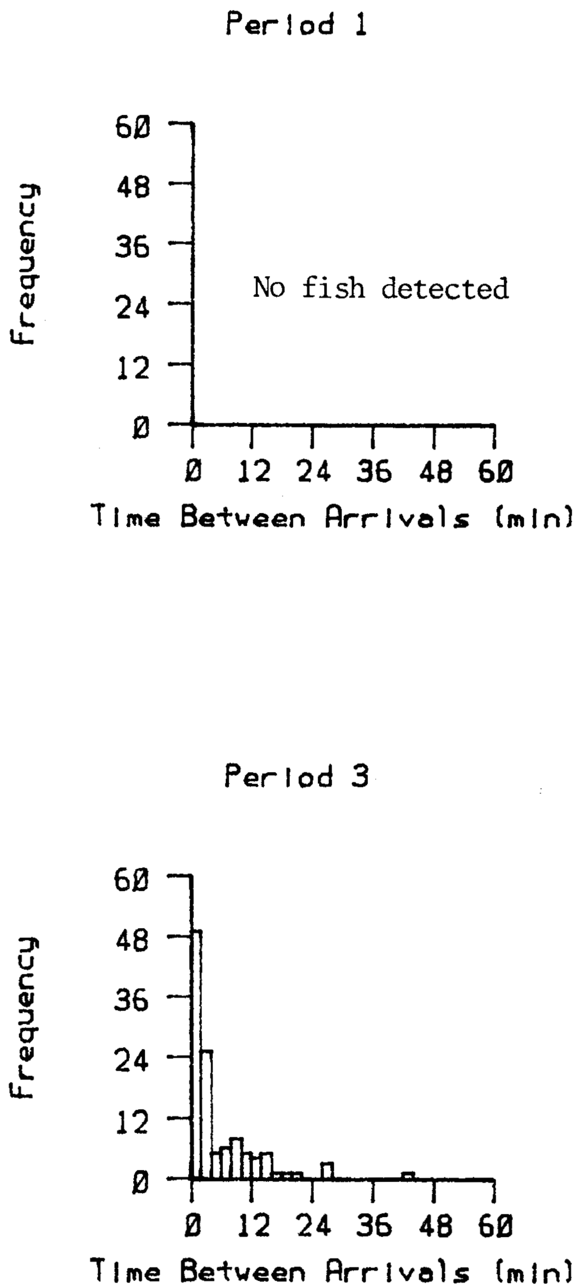

Figure 11. Frequency distribution of time (minutes) between successive arrivals of upriver migrant fish in the Stikine River at the north and south bank sonar sites, by period, 1983.

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APPENDICES

Appendix 1. Stikine River bottom profile at the north bank sonar site[1], 14 June 1983.

Distance (m)	Depth (m)	Distance (m)	Depth (m)
0 (North Bank)	0	193.2	5.4
4.6	3.3	204.2	5.3
15.5	4.4	215.5	5.2
26.8	6.1	226.5	5.1
37.8	7.0	237.4	5.1
49.1	6.7	248.7	5.0
60.0	6.6	259.7	5.0
71.0	6.7	271.0	5.1
82.3	6.7	281.9	5.2
93.3	6.7	292.9	5.6
104.5	6.4	304.2	6.1
115.5	6.3	315.2	6.3
126.5	6.2	326.4	6.8
137.8	6.1	337.4	7.6
148.7	5.9	348.4	7.7
160.0	5.8	359.7	3.1
171.0	5.7	370.6	2.6
182.0	5.7	375.2	(South Bank) 0

1 Recorded depths were taken along a transect angled 15° downstream from perpendicular to the shoreline. River width of 362.4m was taken from USGS data. Transect length of 375.2m was estimated by 362.4/Cos 15°.

Appendix 2. Stikine River bottom profile at the south bank sonar site[1], 14 June 1983.

Distance (m)	Depth (m)	Distance (m)	Depth (m)
0 (South bank)	0	248.7	5.0
11.3	3.6	260.0	5.8
22.6	3.9	271.3	5.8
33.8	3.6	282.8	5.7
45.1	3.7	294.1	5.9
56.7	3.8	305.4	6.2
68.0	4.1	316.7	6.3
79.2	4.0	328.0	6.5
90.5	4.1	339.2	6.6
101.8	4.1	350.5	6.2
113.1	4.6	361.8	6.6
124.4	4.7	373.1	6.7
135.6	4.7	384.4	7.1
146.9	4.8	395.6	7.7
158.2	4.9	407.2	7.8
169.5	5.2	418.5	8.3
181.1	4.7	429.8	8.9
192.3	4.8	441.0	9.3
203.6	4.8	452.3	9.7
214.9	5.8	463.6	7.8
226.2	5.5	474.9	6.0
237.4	5.1	486.2	(North Bank) 0

[1] Recorded depths were taken along a transect angled 15° downstream from perpendicular to the shoreline. River width of 457.2m was estimated. Transect length of 486.2m was estimated by 457.2/Cos 15°.

Appendix 3. Stikine River depth fluctuation during sonar sampling, 1983[1].

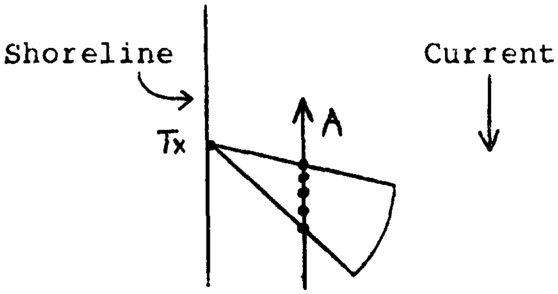
Date	Daily Low Water (m)	Daily High Water (m)	Mean Gauge Height (m)
14 June	5.73	5.90	5.80
15 June	5.73	5.98	5.83
16 June	5.98	6.10	6.06
09 July	6.01	6.09	6.04
10 July	6.08	6.33	6.22
11 July	5.86	6.32	6.13
12 July	5.56	5.85	5.68
13 July	5.39	5.56	5.49
28 July	5.88	6.02	5.98
29 July	5.98	6.02	6.00
30 July	5.91	5.97	5.92
31 July	5.95	6.40	6.18
01 August	6.27	6.46	6.41

1 Data were taken by USGS at a gauging station located near the north bank sonar site (USGS 1984).

Appendix 4. Criteria for classification of targets.

Classification of targets as upriver migrant fish (as opposed to debris, boat traffic, or seals) was based on direction of movement, amount of time spent in the beam, surface turbulence associated with the target, and width and intensity of the recorded trace.

Direction of movement was determined using change-in-range techniques. The figure below shows a cross section of an acoustic beam.



The trajectory of a fish passing through the beam is represented by vector A. Marks on the line identify positions along the trajectory where the fish is ensonified during successive transmissions. As the fish moves along its upstream trajectory, its slant range from the transducer decreases. Downstream movement is evidenced by increasing slant range. Change-in-range is apparent both on an oscilloscope at the time of detection, and on the echogram. Determination of target direction separated debris from other targets.

In order to distinguish fish from other upstream-directed targets (boats and seals), observations made at time of detection and post-season analysis of trace size and intensity and associated turbulence were used. Surface turbulence distinguished boats from seals and fish. Intensity and width of the trace, which are directly related to target size, permitted separation of traces made by seals from those made by fish.

Appendix 5. Normalizing constants used in determination of horizontal distribution of fish in the Stikine River, 1983.

Range (m)	Area (m^2)	Range (m)	Area (m^2)	Normalizing Constant
0- 10	5.24	0- 10	5.24	10.00
0- 20	20.94	10- 20	15.70	3.34
0- 30	47.12	20- 30	26.18	2.00
0- 40	83.78	30- 40	36.66	1.43
0- 50	130.90	40- 50	47.12	1.11
0- 60	188.50	50- 60	57.60	0.91
0- 70	256.56	60- 70	68.06	0.77
0- 80	335.10	70- 80	78.54	0.67
0- 90	424.12	80- 90	89.02	0.59
0-100	523.60	90-100	99.48	0.53
0-110	633.55	100-110	109.95	0.48
0-120	753.98	110-120	120.43	0.44
0-130	884.88	120-130	130.90	0.40
0-140	1.026.25	130-140	141.37	0.37
0-150	1,178.10	140-150	151.85	0.34

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